Lessoned learned from deep soil gas profiles in a fractured aquifer at an ammunition factory in Israel

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Background/Objectives. An ammunition factory complex, owned by Israel Military Industries Ltd., operated on an area of 70 acres in central Jerusalem from 1955 until 1995. After being shut-down, the factory was demolished, debris was removed and the site has since been left undeveloped. A preliminary investigation was conducted, which included a historical survey, shallow passive and active soil-gas surveys and several soil investigations. The results of the preliminary investigation indicated that the soil and soil-gas were contaminated with chlorinated solvents and metals, posing a threat to public health, groundwaterand preventing local urban development. Elevated levels of Volatile Organic Compounds (VOC) were also detected in basements of building located hundreds of meters from the site.

The purpose of the current investigation was to conduct a short-term site characterization investigation to define the source of contamination in the groundwater and in the soil-gas, as an initial step for understanding the scope of the contamination on-site prior to development.

Approach/ Method. The site is located on the outcrops of the mountain aquifer, which is typically characterized by cracks, faults and karstic features. The local lithology consists of six meters of clay soil followed by layers of chalk with marl, limestone and limestone with marl. The groundwater is located at around 100 meters below ground level. Three wells were drilled within the three main contamination hot spots, which were identified during the initial investigations. The monitoring wells were drilled up to 120 meters deep. In one of the monitoring wells, a series of six soil-gas sensors were installed at 6, 15,38,64,76 meters below ground level, in order to obtain a soil-gas profile from the surface to the groundwater level. Groundwater samples were collected and analysed for VOC and soil-gas samples were collected and analysed following the TO-15 method.

Results. The concentration of PCE, TCE, 1-1 and DCE in the groundwater were: 1445 ppb, 250 ppb, and 22 ppb, respectively. The concentration of PCE detected in the soil-gas at 6, 15, 38, 64, 76 meters below ground level was: 494,200, 223,389, 235,874, 68,000 and 125,000 $\mu g/M^3$, respectively. The concentration of TCE detected in the soil-gas at 6, 15, 38, 64, 76 meters below ground level was: 580,875, 91,963, 58,520, 17,238 and 67,639 $\mu g/M^3$, respectively. The deep (76 meter) soil-gas sensor showed that the groundwater is a major source for high concentration of VOCs in soil-gas. Additionally, the soil-gas profile showed a notable increase in the concentrations of PCE, TCE and 1-1 DCE in the soil layers closer to the ground surface. One possible reason for this phenomenon may be the effect of the upper clay layer that potentially could obstruct or limit the ventilation route of the VOC.

Lessons Learned. Groundwater contamination in karstic media can lead to elevated concentrations of VOCs in soil-gas along deep unsaturated zone. The soil gas profile obtained from deep monitoring well showed little or no evidence of dilution-attenuation with depth, as opposed to dilution-attenuation that is known in porous media. Additionally, due to preferential flow and other structural characteristics typical of karstic media, soil-gas contamination has the potential to affect large areas in karstic systems.